

**California Regional Water Quality Control Board
Santa Ana Region**

August 13, 2004

ITEM: 18

SUBJECT: Newport Bay/San Diego Creek Watershed Total Maximum Daily Load
(TMDL) Triennial Review

DISCUSSION

The nutrient TMDL for the Newport Bay watershed in Orange County was adopted by the Regional Board in April 1998 and approved by U.S. EPA in April 1999. The TMDL specifies a 15-year compliance period to achieve the primary numeric target of the TMDL: a 50-percent reduction in nutrient loads to Newport Bay. This numeric target was established to ensure achievement of the narrative water quality objective for Newport Bay regarding algae.

The implementation plan for the TMDL includes a commitment by the Regional Board to evaluate the TMDL at least once every three years. A detailed report of that evaluation by staff is attached. The following is a summary of the salient points presented in the report.

The first compliance target for the TMDL, a 30 percent reduction in nutrient loads by the 2002 summer season, has been achieved; in fact, the 2002 summer season loads were well below the final 50 percent reduction required by 2007. This is largely due to three factors: lower rainfall, nitrogen removal in the Irvine Ranch Water District (IRWD) wetlands, and implementation of nitrogen runoff control measures, particularly at the large nurseries regulated by Waste Discharge Requirements and by the Silverado/Caltrans denitrification facility.

Algal biomass in Newport Bay has decreased significantly since the TMDL was adopted in 1998; blooms are now largely restricted to the Upper Bay and are less extensive than in the years prior to adoption of the TMDL. However, these blooms are still large enough to impair recreational and habitat beneficial uses, in Newport Bay.

The continued presence of the algal blooms, despite achievement of the TMDL load targets, suggests that more restrictive water quality objectives (WQOs) are required in San Diego Creek. This in turn would require more conservative (lower) TMDL allocations for dischargers in the Newport Bay watershed.

The TMDL implementation plan requires the review of established nitrogen water quality objectives for San Diego Creek, and revision of those objectives as necessary. The TMDL called for this task to be completed by December 31, 2000. However, completion

of this task has been delayed by the scientific complexity of macroalgal-nutrient interactions and the need to complete on-going relevant field investigations. The results of these investigations will be used to develop a quantitative link between nitrogen concentrations and water quality impairments. The methodology will rely on numeric modeling of macroalgal biomass as a function of nutrient inputs to Newport Bay and the resulting impacts on dissolved oxygen levels. This task will likely not be completed prior to 2007.

In the interim, nutrient source control measures continue to be implemented. Three of the four large nurseries in the watershed have greatly reduced their discharges through recycling. A draft permit incorporating nutrient load limits has been developed for the fourth nursery and will be considered for adoption by the Regional Board in the near future. Management practices for agricultural areas have been developed and disseminated, and urban areas will be similarly addressed. Legacy nitrate concentrations in groundwater are being addressed by incorporating load limits into waste discharge requirements for groundwater cleanup and groundwater dewatering projects.

Additional measures under consideration by the stakeholders, particularly the proposed IRWD natural treatment system (NTS), have the potential to greatly reduce nutrient loading to Newport Bay.

Investigations carried out over the past five years have provided data to revise and update the TMDL. Recommended TMDL revisions are expected to include updating the "undefined" source load category to reflect new source characterization data, and recalculating urban and agricultural load allocations to reflect land use changes. Wasteload allocations will also need to be revised to include specific discharges and to delete allocations for certain discharges that do not occur. The workload associated with processing Basin Plan amendments is significant. In the interest of the most efficient use of staff resources, particularly in light of other high priority work to complete implementation plans and Basin Plan amendments for the toxics TMDLs for the watershed promulgated by the U.S. EPA, staff recommends that these changes be considered together with specific recommendations for revised water quality objectives for San Diego Creek. As noted, the investigations necessary to complete review and revision of these objectives are underway and expected to be complete by 2007. Staff believes that no adverse water quality or beneficial use impacts will result from the delay in consideration of the changes in a single, future Basin Plan amendment.

The nutrient TMDL triennial review staff report is being presented as an information item only. The Regional Board is not required to take an action on the report.

California Regional Water Quality Control Board
Santa Ana Region

**NEWPORT BAY WATERSHED NUTRIENT TMDL
TRIENNIAL REVIEW REPORT**

July 28, 2004

TABLE OF CONTENTS

	<u>Page No.</u>
EXECUTIVE SUMMARY	iii
1.0 INTRODUCTION	1-1
1.1 Physical Setting	1-1
1.2 Land Use	1-2
1.3 Water Quality Objectives and Beneficial Use Impairment	1-3
1.4 Dischargers in the Watershed	1-3
1.5 TMDL Development and Adoption	1-4
2.0 COMPLIANCE SUMMARY – 2002 SUMMER SEASON	2-1
2.1 Overall Summary	2-1
2.2 Water Quality Objectives in San Diego Creek	2-3
2.2.1 San Diego Creek Reach 1	2-3
2.2.2 San Diego Creek Reach 2	2-4
2.3 Phosphorus Allocations	2-5
2.4 Compliance by Discharge Category	2-5
2.4.1 Nurseries	2-5
2.4.2 Agriculture	2-7
2.4.3 Urban Runoff	2-9
2.4.4 Silverado Constructors/CALTRANS	2-10
2.4.5 Groundwater Cleanup	2-10
2.4.6 Groundwater Dewatering	2-11
2.4.7 Rising Groundwater	2-11
2.4.8 Open Space Runoff	2-12
2.4.9 Atmospheric Deposition	2-13
2.4.10 In-Bay Nitrogen	2-14
2.4.11 Other Sources	2-15
2.5 San Joaquin Marsh – IRWD and UCI Wetlands	2-15
3.0 MACROALGAL TRENDS IN NEWPORT BAY	3-1
4.0 TASK STATUS AND SCHEDULE	4-1
5.0 CONCLUSIONS/RECOMMENDATIONS	5-1
6.0 REFERENCES	6-1

LIST OF TABLES

	<u>Page No.</u>
1-1 Land Use in the Newport Bay Watershed.....	1-3
1-2 Discharge Permits Relevant to the TMDL.....	1-4
1-3 Seasonal TMDL Allocations.....	1-5
2-1 Overall 2002 Total Nitrogen Summer Discharge Summary.....	2-1
2-2 TMDL Summer 2002 Compliance Summary.....	2-2
2-3 Dry Weather TN, Reach 2: 2002-2003.....	2-4
2-4 Annual Total Phosphorus Load Allocation Targets.....	2-5
2-5 Nursery Allocations – Daily Loads.....	2-6
2-6 Nursery Allocations – Seasonal Loads.....	2-6
2-7 Changes in Agricultural Land Use: 1982-2003.....	2-7
4-1 TMDL Task Status.....	4-1

LIST OF FIGURES

	<u>Page No.</u>
1-1 Newport Bay Watershed.....	1-2
1-2 Nutrient TMDL Final Allocations	1-5
2-1 Overall Load Compliance	2-1
2-2 Summer Season Compliance by Category.....	2-2
2-3 Median Summer Flow Rates in San Diego Creek: 1984-2002.....	2-3
2-4 San Diego Creek - Campus Drive TN and TIN: 2000-2003.....	2-3
2-5 San Diego Creek Reach 2 TN and TIN: 2000-2003.....	2-4
2-6 Hines Nursery Monthly Total Nitrogen Discharge: 1999-2004.....	2-7
4-1 Total Nitrogen Summer Season Loads to Upper Newport Bay Assuming Concentration of 13 mg/L in San Diego Creek	4-2
4-2 Total Nitrogen Summer Season Loads to Upper Newport Bay Assuming Concentration of 5 mg/L in San Diego Creek.....	4-2

EXECUTIVE SUMMARY

This report provides a review of the nutrient Total Maximum Daily Load (TMDL) for the Newport Bay watershed. It evaluates compliance with the TMDL load reduction targets, summarizes studies carried out to characterize previously undefined sources, and provides recommendations to ensure that the goals of the TMDL are achieved.

The nutrient TMDL for the Newport Bay watershed in Orange County was established in April 1998. The TMDL specifies a 15-year compliance period to achieve the primary numeric goal of the TMDL: a 50-percent reduction in nutrient loads to Newport Bay. This numeric goal was expected to be sufficient to achieve the narrative water quality objective for Newport Bay regarding algae.

The first compliance target for the TMDL, a 30 percent reduction in nutrient loads for the 2002 summer season, has been achieved. This is largely due to three factors: lower rainfall, nitrogen removal in the Irvine Ranch Water District (IRWD) wetlands, and implementation of nitrogen runoff control measures, particularly at the large nurseries regulated by Waste Discharge Requirements and the Silverado/Caltrans denitrification facility.

Algal biomass in Newport Bay has decreased significantly since the TMDL was adopted in 1998; blooms are now largely restricted to the Upper Bay and are less extensive than in the years prior to adoption of the TMDL. However these blooms are still large enough to impair water quality and beneficial uses in Newport Bay. The continued presence of the algal blooms despite achievement of the TMDL load targets demonstrates that the numeric nitrogen water quality objectives in San Diego Creek and the TMDL load targets are not sufficiently protective.

The TMDL implementation plan requires the establishment of revised nitrogen water quality objectives; however, completion of this task has been delayed by the scientific complexity of the problem and the need to complete on-going relevant field investigations. The results of these investigations are needed to sufficiently quantify the link between nitrogen concentrations and water quality impairment before new, protective water quality objectives (WQOs) can be determined. The methodology will rely on numeric modeling of macroalgal biomass and dissolved oxygen as a function of nutrient inputs to Newport Bay. It is not likely that new WQOs can be established prior to 2007.

In the interim, nutrient source control measures continue to be implemented. Three of the four large nurseries in the watershed have greatly reduced their discharges through recycling. A draft permit incorporating nutrient load limits has been developed for the fourth nursery and will be scheduled for considered for adoption by the Regional Board in the near future. Management practices for agricultural areas have been developed and disseminated and urban areas will be similarly addressed. Legacy nitrates in groundwater are being addressed by incorporating load limits in discharge requirements for groundwater cleanup and groundwater dewatering projects.

Additional measures under consideration by the stakeholders, particularly the proposed IRWD natural treatment system (NTS), have the potential to greatly reduce nutrient loading to Newport Bay.

Investigations carried out over the past five years have provided data to revise and update the TMDL. Recommended TMDL revisions include updating the “undefined” source load category to reflect new source characterization data, and recalculating urban and agricultural load

allocations to reflect land use changes. Because the workload associated with processing Basin Plan amendments is significant, it is recommended that these changes be considered together with specific recommendations for revised water quality objectives in San Diego Creek. As noted above, the investigations necessary to complete review and revision of these objectives are underway, and expected to be complete by 2007. No adverse water quality or beneficial use impacts are likely to result from the delay in consideration of the changes in a single, future Basin Plan amendment.

1.0 INTRODUCTION

The Santa Ana Regional Water Quality Control Board approved the nutrient Total Maximum Daily Load (TMDL) for the Newport Bay Watershed on April 17, 1998 (Resolution No. 98-9, as amended by Resolution No. 98-100). The State Water Resources Control Board (SWRCB) and the United States Environmental Protection Agency (USEPA) approved the TMDL in November 1998 and April 1999, respectively. The TMDL is currently under implementation.

The goal of the TMDL is to reduce nutrient loading in the Newport Bay watershed to the levels of 1973, when the beneficial uses of the Bay were thought to be unimpaired by excessive algae growth. The identified target is a 50% reduction in loading relative to an eight-year baseline average. This reduction was expected to result in attainment of the established narrative water quality objectives in Newport Bay relating to eutrophication.

1.1 Physical Setting

The Newport Bay watershed encompasses 154 square miles and includes portions of Newport Beach, Irvine, Laguna Hills, Lake Forest, Tustin, Orange, Santa Ana, and Costa Mesa. The watershed is defined by foothills of the Santa Ana Mountains to the east, and the San Joaquin Hills to the west and southwest. Average rainfall is approximately 13 inches per year, with about 90 percent occurring between November and April. Runoff from the hills drains across the Tustin Plain and enters Upper Newport Bay primarily via San Diego Creek, the major freshwater tributary to Newport Bay (**Figure 1-1**).

The San Diego Creek watershed contained few stream channels prior to 1900 (Trimble 1998). Runoff from the watershed collected in a large swamp (the Swamp of the Frogs) that occupied low-lying areas in Tustin, Santa Ana, and Irvine (roughly bounded by the 5 and 405 freeways, Culver Dr., and extending towards Fairview Dr. in Santa Ana). Rising groundwater fed the swamp, and an adjacent ephemeral lake that existed immediately west of the swamp. Runoff occasionally overflowed to the north to enter the Santa Ana River, but a low ridge prevented runoff from flowing west and entering Upper Newport Bay.

In the early 1900s, agricultural crop production began to assume prominence over ranching, and drainage channels were constructed in the Swamp of the Frogs. The low ridge that had blocked water movement into Newport Bay was breached and runoff was directed toward the San Joaquin Marsh. The present San Joaquin Marsh is a remnant of a much larger wetland ecosystem that existed along ancestral channels of the Santa Ana River. In the succeeding decades, the drainage network in the San Diego Creek watershed was expanded to serve the needs of agriculture and urbanization in the watershed. In 1968, the channel network was widened and straightened to contain the projected 100-year flood, and San Diego Creek was isolated from San Joaquin Marsh (Trimble 1998).

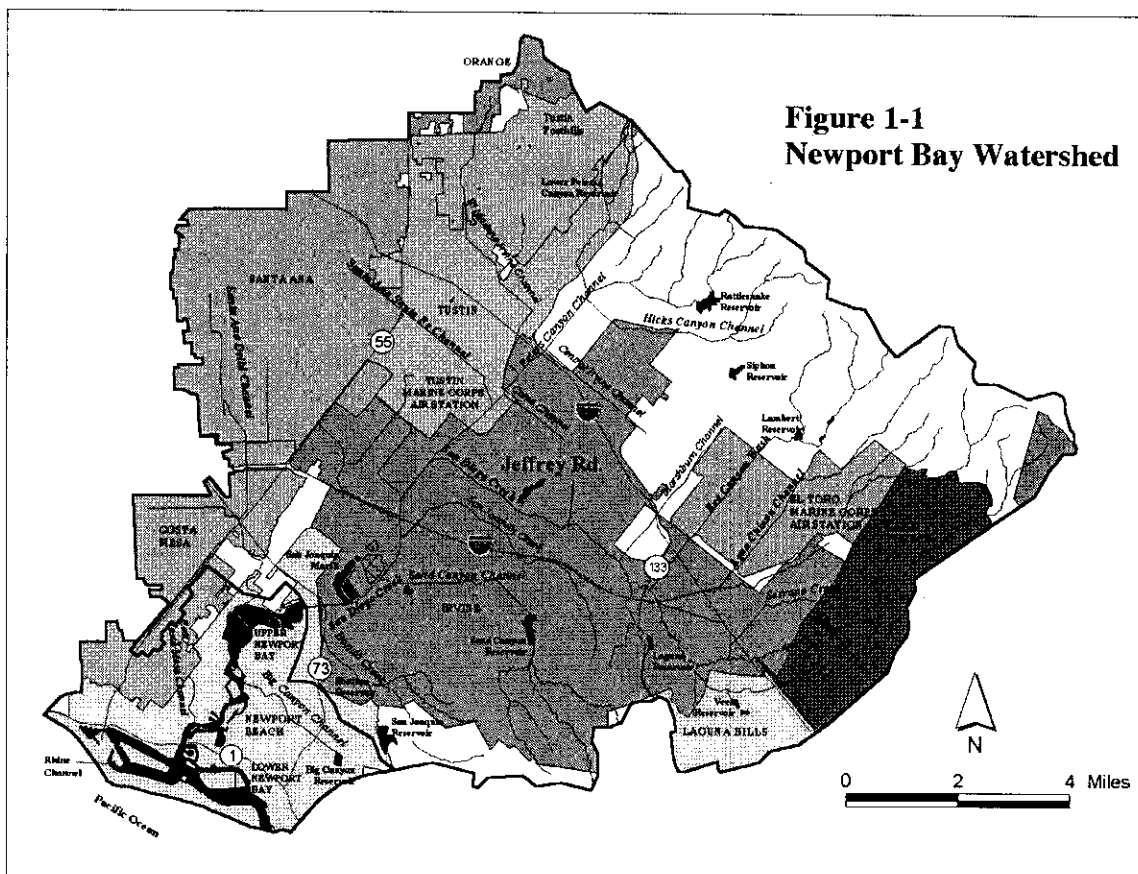
The San Joaquin Marsh currently consists of the 202-acre San Joaquin Marsh Reserve, which is owned and managed by the University of California Natural Reserve System (UCNRS), and a 336-acre eastern portion owned by the Irvine Company and the Irvine Ranch Water District (IRWD).

The Upper Bay estuary contains a State Ecological Reserve in the upper half, with habitat designated for sensitive species. Sediment capture basins in the Upper Bay are dredged

periodically by the Army Corps of Engineers (ACOE). The entire Bay is subject to twice-daily ocean tides, resulting in relatively short residence times of 4-7 days.

San Diego Creek accounts for about 80% by volume of all tributary inflows to Newport Bay. San Diego Creek is divided into two reaches. Reach 1 is located downstream of Jeffrey Road and Reach 2 lies upstream of Jeffrey Road to the headwaters. The Santa Ana Delhi Channel, Big Canyon Wash, and Costa Mesa Channel account for the remaining freshwater input to the bay. The Santa Ana Delhi Channel is the largest contributor, accounting for about 15% of the total. Roughly three-quarters of the total freshwater inflow to the Bay occurs during storm events.

The mean summer season flow rate in San Diego Creek during the 1990-97 baseline period for the TMDL was 13.4 cubic feet per second (cfs). During summer 2003, this had declined to 7.3 cfs largely as a result of low rainfall in the preceding winter seasons, although water conservation measures may have also contributed to the decline.



1.2 Land Use

Land use statistics (**Table 1-1**) illustrate the increasing urbanization of the watershed over the past decades. In 1983, agriculture accounted for 22% and urban uses for 48% of the land use in the watershed. In 1993, agricultural uses accounted for 12% and urban uses for over 64% of the area. As of 2000, agriculture had dropped to approximately 7% (<7,500 acres), including row crops (primarily strawberries and green beans), lemons, avocados and commercial nurseries. Currently, the San Diego Creek watershed is greater than 90% urbanized, while the watershed of the Santa Ana-Delhi channel is over 95% urbanized.

Table 1-1 Land Use in the Newport Bay Watershed				
Land Use	San Diego Creek		Newport Bay Watershed	
	Acres	Percent	Acres	Percent
Agriculture	5,092	6.6%	5,147	5.2%
Open Space	22,350	29.0%	24,398	24.8%
Urban	49,297	64.4%	68,817	70.0%
Total	76,739	100%	98,362	100 %

Source: OCPFRD (2002).

1.3 Water Quality Objectives and Beneficial Use Impairment

Macroalgal blooms were not noted in Newport Bay prior to 1968, when San Diego Creek was extended to Upper Newport Bay. Prior to that time, drainage from the watershed terminated at the San Joaquin Marsh.

"Prior to the introduction of non-storm discharges from San Diego Creek in the late 60's, essentially no nutrient inputs were present; at that time Newport Bay was viewed as healthy and productive" (Orange County Environmental Management Agency [OCEMA]1989).

Large mats of the green algae *Ulva* and *Enteromorpha* have become commonplace in Newport Bay since the early 1970s, with a peak bloom occurring in 1985-86. These seaweeds grow in intertidal mudflats and shallow subtidal areas, attaching themselves to available substrate and floating in the water column. When their length exceeds the height of the water column, they form mats on the water surface. These mats can occupy the entire water column and shade out other plants, resulting in detrimental impacts to the wildlife-related beneficial uses of Newport Bay. The mats can also become detached and transported to locations throughout the Bay. They are often deposited on sandy beaches, where they impair recreational use, and collect in harbor areas, where they impede navigation by becoming entangled in boat propellers.

The macroalgal blooms in Newport Bay have coincided with large increases in nutrient loading to the Bay. Estimated total nitrogen loads were stable at 525,000 to 672,000 pounds from 1973/74 to 1976/77. The loads then tripled in the following year and remained above 1,000,000 pounds for the next 20 years, with the peak year occurring in 1985/86 (1.8 million pounds). Nitrogen data from the eight-year TMDL baseline period 1990-97 shows consistently elevated concentrations of nitrogen relative to existing water quality objectives in Reach 1 and Reach 2 of San Diego Creek. Loads during this period averaged over 1 million pounds of total nitrogen per year.

1.4 Dischargers in the Watershed

The Regional Board has adopted thirteen individual permits, three general permits, and an area-wide stormwater permit that are or were applicable within the watershed.

Table 1-2 Discharge Permits Relevant to the TMDL

Permit	Description
Individual Permits:	
Nurseries	3 individual WDRs, 1 additional in preparation
Silverado/Caltrans	Large dewatering/denitrification operation
Tustin Desalter	Water supply facility (groundwater treatment)
IRWD WWSP	Project not implemented (<i>permit expired in 1999</i>)
General Permits:	
Groundwater Cleanup	34 enrollees as of Jan 2002
Groundwater Dewatering	12 enrollees as of 2002
Stormwater:	
Orange County MS4 permit	Orange County and 6 co-permittees

Permits that include load allocations developed as part of the nutrient TMDL are shown in **Table 1-2**. Several other facilities (including one landfill) have Waste Discharge Requirements, but they are not included in the nutrient TMDL as they do not discharge nutrients. Six boatyard operations in Newport Beach were enrolled under a general NPDES permit. This permit prohibited discharge of wastewater to Newport Bay, with the exception of stormwater runoff after the first 1/10th inch of precipitation. The general permit was rescinded and the boatyard operations are now covered under the State Board's General Industrial Stormwater permit. The boatyards are not included in the nutrient TMDL. There are no sewage treatment plants in the Newport Bay Watershed that discharge effluent to the drainage channels or Newport Bay.

1.5 TMDL Development and Adoption

The TMDL was designed to achieve a 50-percent reduction in non-storm nutrient loads. Non storm-loads are defined as those that occur when the San Diego Creek flow rate at Campus Drive is less than 50 cfs. The 50 cfs threshold level was included in the TMDL to account for the rapid transport of nutrients through the bay and out to the ocean during storm events. Storm events can cause a freshwater lens to develop on top of the saline bay waters, thereby isolating the nutrient load and conveying it out to the ocean in a matter of days. Nutrient loads that exit the Bay in a short period of time during the winter season are not expected to be available for uptake by macroalgae.

The TMDL 50-percent reduction was established relative to average loads calculated from an eight-year baseline period (1990-97). The overall annual target of 298,225 lbs is divided into a summer season allocation (153,861 lbs) and a winter season allocation (144,364 lbs). The winter season allocation was calculated by assuming 67 non-storm days. Compliance is to be achieved in stages: a 30% and 50% reduction in summer loads by 2002 and 2007, respectively, and a 50% reduction in winter loads by 2012.

The summer season is defined as April through September, while the winter season is October through March. A seasonal approach was used because it was generally agreed that the summer season was the more critical time period for macroalgal blooms, and consequently, that nutrient reduction efforts should be prioritized for the summer. It is possible for the macroalgae to persist through the winter, however, the conditions for rapid growth are generally restricted to the summer season. The winter season compliance period was extended to 2012 to allow additional data to be gathered to assess the importance of and need for winter nutrient controls. Significant uncertainty still exists regarding how much of the nutrient load that enters the bay in the winter is available for macroalgal growth.

**Figure 1-2: Nutrient TMDL Final Load Allocations
(by summer 2007 and winter 2012)**

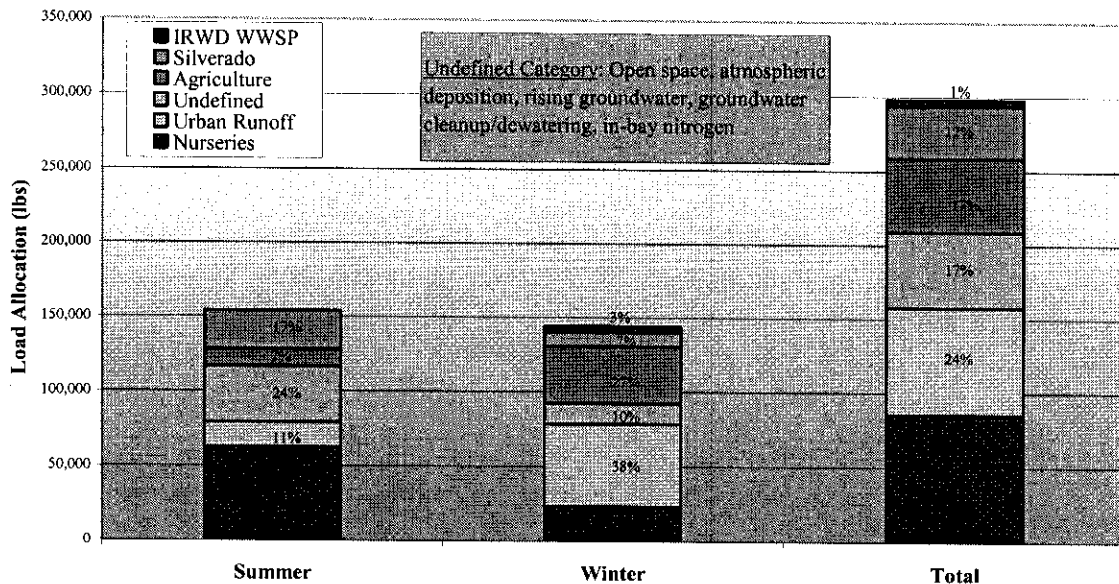


Figure 1-2 and **Table 1-3** show the overall final TMDL allocations, as well as the seasonal summer and winter allocations, for the main categories of discharge. The largest allocation is for the nurseries: 29% of the total overall and 41% in the summer season. Urban runoff is second, with 24% of the overall total and 11% in the summer season. The “undefined” category is the next largest (17% overall and 24% in the summer season). This category includes the following disparate sources: atmospheric deposition, in-bay nitrogen, open-space runoff, rising groundwater, and groundwater cleanup and dewatering operations. These sources were placed in the undefined category because insufficient information was available in 1998 to accurately characterize the loadings and determine individual allocations. The TMDL implementation plan specified that investigations be undertaken to collect data sufficient to characterize these sources. The remaining discharge allocations are for agriculture and the Silverado/Caltrans denitrification facility.

Table 1-3: Seasonal TMDL Allocations

Discharger	Summer		Winter	Total
	by 2002	by 2007	by 2012	by 2012
Hines Nursery	40,992	38,613	14,227	52,840
Bordiers Nursery	12,993	12,261	4,518	16,779
El Modeno Gardens Nursery	7,869	7,320	2,697	10,017
Un-permitted Nurseries	5,490	4,392	1,618	6,010
Urban Runoff	20,785	16,628	55,442	72,070
Agriculture	22,963	11,481	38,283	49,764
Silverado/CALTRANS	25,671	25,671	9,459	35,130
IRWD WWSP (expired)	0	0	4,181	4,181
Undefined	63,334	37,495	13,939	51,434
Total	200,097	153,861	144,364	298,225

2.0 COMPLIANCE SUMMARY – 2002 SUMMER SEASON

2.1 Overall Summary

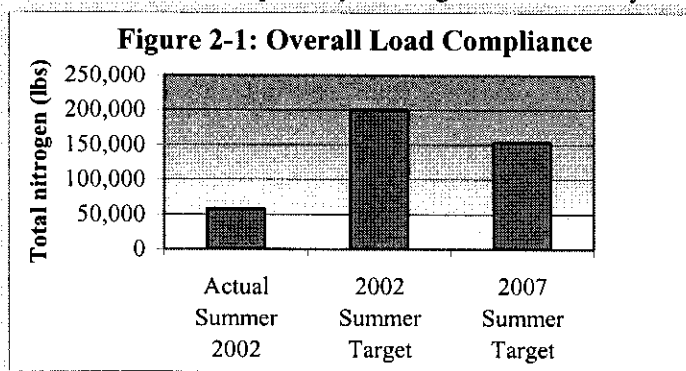
About 58,171 lbs of total nitrogen was discharged to Newport Bay during the 2002 summer season. The overall total nitrogen discharge summary for the summer season 2002, calculated largely from data submitted under the Regional Monitoring Program (RMP), is presented in **Table 2-1**.

Table 2-1: Overall 2002 Total Nitrogen Summer Discharge Summary

Source	Load (lbs)	% of Total	% of Target	Subwatershed Export Rates (lbs/acre)
E. Costa Mesa	187	<0.5%	<0.5%	0.215
Bonita Canyon	691	1%	<0.5%	n/a
Santa Ana Delhi	8,686	15%	4%	0.601
San Diego Creek	45,507	80%	23%	0.585
Atm. Deposition	1,476	3%	<1%	---
In-bay nitrogen	unknown			
Subtotal	56,547	100%	28%	
San Joaquin Marsh	+33,000			
Without Marsh	89,547		45%	

n/a = not available

The subtotal in **Table 2-1** represents the nitrogen load to Upper Newport Bay as measured by the monitoring stations on the tributaries entering the bay. The confluence of Bonita Canyon and San Diego Creek is located downstream of the San Diego Creek monitoring station at Campus Drive, therefore it is listed separately although it is a tributary to San Diego Creek. As shown in **Figure 2-1**,



2-1, the calculated nitrogen loading to the Bay for the 2002 summer season is substantially below the interim (2002) and final (2007) TMDL summer season target. The largest load is delivered by San Diego Creek, as measured at Campus Drive, downstream of the intake and return location for water diverted to the IRWD San Joaquin Marsh wetlands. According to an evaluation of the marsh performed

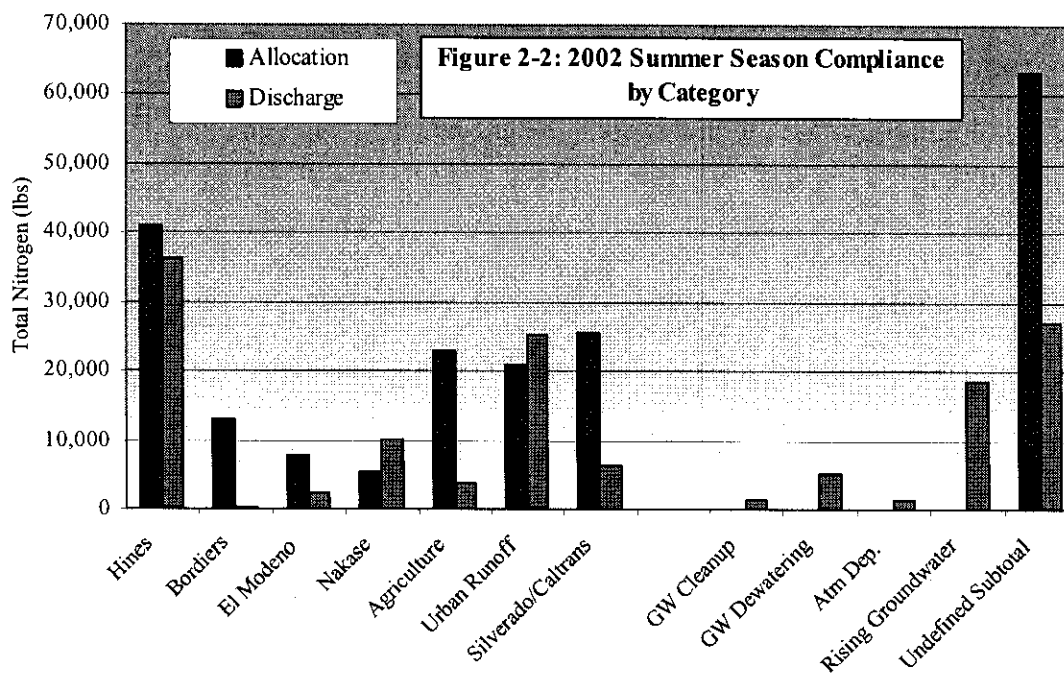
by IRWD, approximately 66,000 lbs of nitrogen was removed from San Diego Creek in 2002 as a result of diverting roughly half the creek flow through the marsh (IRWD, 2003 [presentation]). Although detailed flow and concentration data have not been made available, assuming that 50% of this reduction occurred in the summer season, roughly 33,000 lbs was removed via the marsh diversion in summer 2002. The IRWD San Joaquin Marsh wetlands are described further in **Section 2.5**. It should be noted that the overall load to Newport Bay does not include in-bay nitrogen sources, which remain to be quantified (see **Section 2.4.10**)

Table 2-2 presents an evaluation of the actual loads for the 2002 summer season versus the TMDL allocations. The loads in **Table 2-2** were largely generated using permit monitoring data. This is a different source of data than the channel monitoring data used in **Table 2-1**. Except for

the rising groundwater load, the loads in **Table 2-2** do not account for in-stream denitrification or other loss mechanisms that occur prior to discharge into Newport Bay. As a result, the total loads calculated in **Table 2-2** exceed those shown in **Table 2-1**. **Figure 2-2** graphically depicts the compliance evaluation data presented in **Table 2-2**.

Table 2-2: TMDL Summer 2002 Compliance Summary

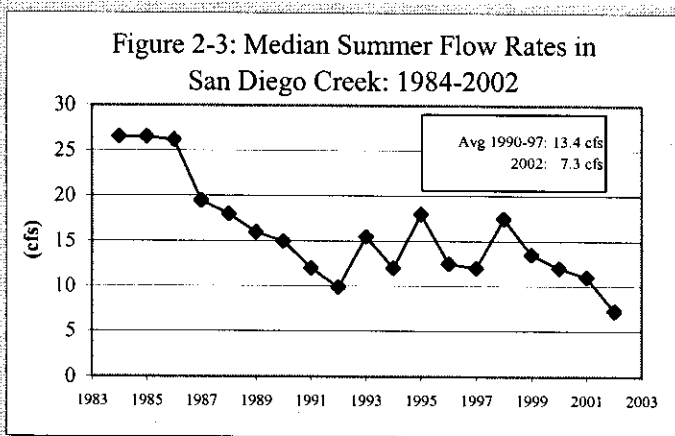
Discharger	Total Nitrogen Loads (lbs)			Comment/Data Source
	Allocation	Actual	Used	
Hines Nursery	40,992	36,409	89%	Permit file – monthly reports
Bordiers Nursery	12,993	267	2%	Permit file – monthly reports
El Modeno Nursery	7,869	2,382	30%	Permit file – monthly reports
Nakase Nursery	5,490	10,047	183%	Estimated from Hines per acre rate
Agriculture	22,963	3,873	17%	UC Coop. Extension (2003)
Urban Runoff	20,785	25,391	122%	Using RMP-specified channels
Silverado/Caltrans	25,671	6,516	25%	Permit file – monthly reports
Tustin Desalter	-	148	-	Discharge previously not in TMDL
Defined Source Subtotal	136,763	85,033	62%	
Open Space	-	0		No summer runoff; Meixner et al (2004)
GW Cleanup	-	1,574		60% is Tustin Marine Station
GW Dewatering	-	5,277		87% is City of Irvine (Culver, Jamboree)
Atmospheric Dep.	-	1,476		Meixner et al (2004)
Rising Groundwater	-	18,658		Ultimate discharge to Upper Newport Bay (see Sec. 2.4)
In-Bay Nitrogen	-	Unknown		SCCWRP project underway; see Sec. 2.4
Undefined Source Subtotal	63,334	26,985	43%	Not including in-bay nitrogen sources
Grand Total	200,097	112,018	56%	Also below 2007 target of 153,861 lbs



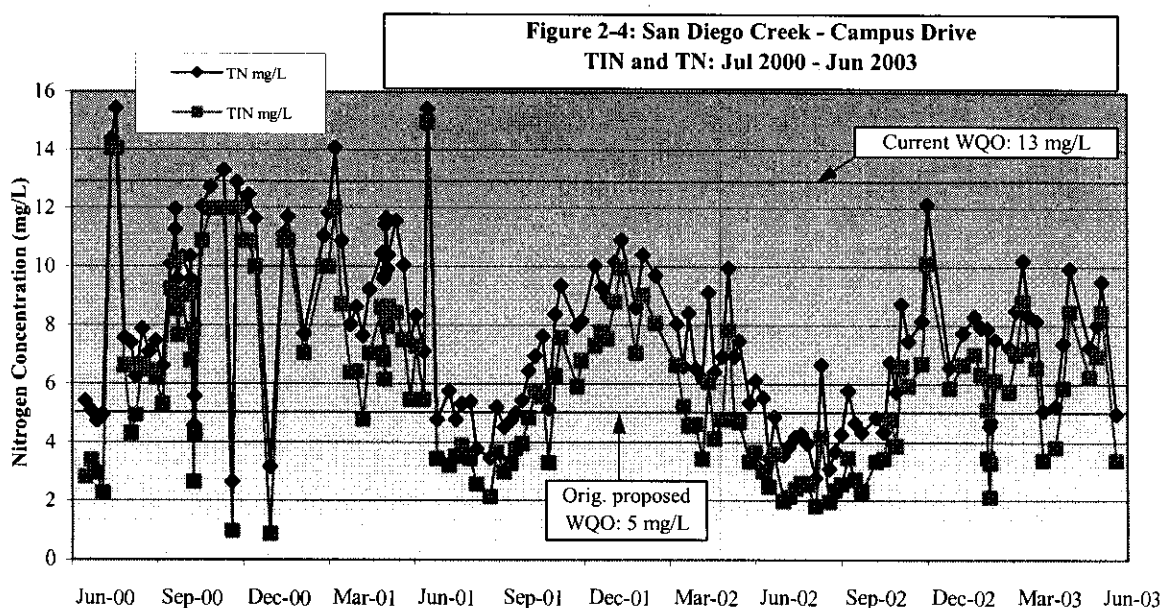
2.2 Water Quality Objectives in San Diego Creek

2.2.1 San Diego Creek Reach 1

Dry-weather total inorganic nitrogen concentrations in San Diego Creek at Campus Drive averaged 10-11 mg/L from 1966 to 1969, but then increased steadily to over 25 mg/L in the mid-1980s. Concentrations subsequently declined to levels similar to those of the early 1970s (SCCWRP 2001). Average summer season nitrogen concentrations during the 8-year TMDL baseline period (1990-97) were 14.8 mg/L TIN (equivalent to approximately 16 mg/L TN).



These concentrations exhibited a sharp decline to an average of 5.6 mg/L TN for the 2002 summer season (Figure 2-4) and were substantially below the existing water quality objective of 13 mg/L TIN in Reach 1 of San Diego Creek. The objective in Reach 2 of San Diego Creek, 5 mg/L TIN, was also proposed for Reach 1 during development of the 1983 Basin Plan, however, the Regional Board directed staff to re-examine this objective because of economic/attainability considerations. Staff then averaged the low-flow concentrations from the SD Creek - Campus monitoring station to derive the 13 mg/L TIN objective (SARWQCB 1997).

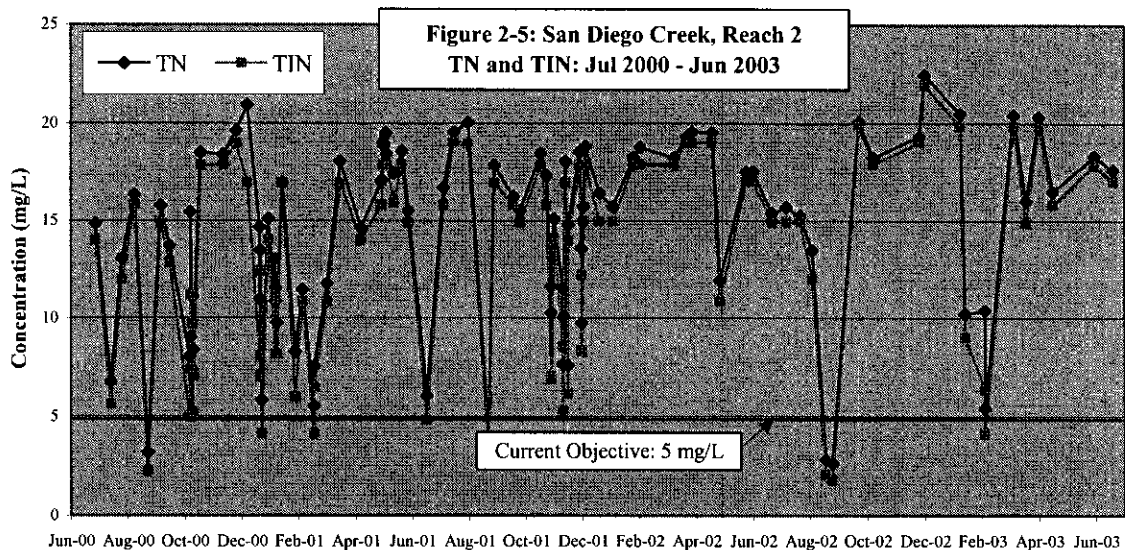


The pronounced seasonal variation in the nitrogen concentrations seen in **Figure 2-4** is due to a combination of factors: higher groundwater levels, and thus higher groundwater loads in winter and spring (flushing of the high nitrate vadose zone and increased amounts of poor quality groundwater rising into surface channels), the lower efficiency of San Joaquin Marsh and other denitrification processes in the channel during the winter months as opposed to the summer months, peak nitrogen loading from row crops as strawberry plants get established, peak loading from nurseries as they process the highest volume of plants, and additional factors.

Flow rates have also declined to about 54% of the baseline summer flow rates; 7.3 cfs in 2002 versus 13.4 cfs in 1990-97 (**Figure 2-3**). The decline in flow rates means that the nitrogen loads have declined by about 50 percent solely due to the reduced freshwater input to the Bay. Aside from climatic factors, reasons for the declining flow rates include increased water conservation measures in urban areas (such as tiered pricing) and more efficient agricultural practices, especially recycling and computerized irrigation at three large nurseries in the watershed after the establishment of a stakeholder nutrient taskforce in 1985.

2.2.2 San Diego Creek Reach 2

Reach 2 of San Diego Creek is the section of the creek upstream of Jeffrey Road (**Figure 1-1**). The water quality objective for Reach 2, 5 mg/L TIN, is not being achieved (**Figure 2-5**). Concentrations greatly exceed the objective, and there is no trend apparent that indicates progress towards achieving the objective. Future actions that should contribute to achieving the objective are appropriate limitations in waste discharge requirements for the City of Irvine dewatering at the Culver underpass and for the Nakase Brothers nursery. These waste discharge requirements are expected to be considered by the Regional Board in 2004.



The TMDL specifies a 14 lbs/day load allocation (on an annual basis) during non-storm conditions for Reach 2, with compliance required by 2012 at the latest. Based on data from July 2000 to June 2003 (**Table 2-3**), it appears that compliance with this target may not be feasible. The average dry weather load was 213 lbs/day, and the average dry weather flow rate was 2.9 cfs. Even assuming a

	Conc. (mg/L)	Flow (cfs)	Load (lbs/day)
Min:	2.6	0.5	6.8
Max:	22	24	1,761
Avg:	15.6	2.9	213
Median:	16.9	1.5	138

concentration of 5 mg/L TN, the load at the average flow rate is 43 lbs/day. Achieving 14 lbs/day would require a concentration of about 0.9 mg/L TN. This assumes the dry weather flow rate remains similar to that observed during 2000-2003, although these were low rainfall years, and the long-term flow rate is likely higher.

2.3 Phosphorus Allocations

The nutrient TMDL specifies phosphorus load targets for four general categories of discharge (Table 2-4). Because phosphorus loading is largely determined by the amount of sediment, the nutrient TMDL states:

“The primary reduction of phosphorus loading is expected to be achieved by the implementation of the TMDL for sediment in the Newport/San Diego Creek watershed. The sediment TMDL is incorporated in to the nutrient TMDL by reference.”

Table 2-4: Annual Total Phosphorus Load Allocation Targets (lbs/yr)

Source	2002	2007
Urban Areas	4,102	2,960
Construction Sites	17,974	12,810
Agriculture	26,196	18,720
Open Space	38,640	27,590
Total	86,912	62,080

The sediment TMDL was adopted in 1998 and is currently being implemented. Sediment loading to Newport Bay has been well below the annual TMDL load targets for the years 2000 to 2003; sediment discharges measured at monitoring stations in San Diego Creek during 2001-2002 were the lowest recorded since monitoring began in 1982-83, reflecting lower rainfall during this period (OCPFRD, 2002, 2003). Consequently, phosphorus loads for the 2002 summer season were an order of magnitude below the

TMDL allocation targets.

The major sources of sediment identified in the sediment TMDL are open space runoff and agriculture, followed by construction sites and urban areas. Erosion of unstable stream banks, such as Serrano Creek in 1998/99, is also a source of sediment. TMDL implementation activities and restoration of Serrano Creek should help reduce sediment transport into San Diego Creek. Additional BMPs targeting the remaining agricultural areas and increased inspections of construction sites may also reduce sediment loads.

2.4 Compliance by Discharge Category

The nutrient TMDL load and wasteload allocations can be grouped into ten discharge categories. Nutrient loads from these discharges are discussed in the following subsections. Note that for the purpose of this discussion, discharges grouped in the “undefined” source category in the TMDL are addressed individually. These are groundwater cleanup and dewatering discharges, rising groundwater, open space runoff and atmospheric deposition.

2.4.1 Nurseries

There are four large nurseries and a number of smaller nurseries in the watershed. The three largest nurseries were issued WDRs in 1990 that limited their discharges of nitrogen. In response, the nurseries implemented a number of BMPs to comply with the WDRs.

Nurseries as a group constitute the largest nutrient load source in the watershed. The TMDL allocates about 34% of the 2002 summer load to the nurseries. The allocations established in 1990 by the initial WDRs, represented a 32% reduction in total nursery load when compared to loading

rates in 1987. These allocations were further reduced in the TMDL, as shown in **Tables 2-5 and 2-6** below.

Table 2-5: Nursery Allocations – Daily Loads

Nursery	Area (acres)	1990 NO ₃ -N Allocation (lbs/day)	2002 TN Allocation (lbs/day)	2007 TN Allocation (lbs/day)
El Modeno	95	50	43	40
Bordiers	242	84	71	67
Hines	453	264	224	211
Unpermitted (Nakase)	125	-	30	24
Total	915	398	368	342

The new TMDL allocations are being included in revised WDR permits. Revisions to the Bordiers WDRs occurred in December 2002 and October 2003. Revision of the Hines and El Modeno WDRs is expected to be considered by the end of 2004.

The TMDL directed that nurseries over five acres in size and discharging nutrients to the watershed in excess of 1 mg/L be issued discharge permits (WDR). After review of nursery operations, the only un-permitted nursery in the watershed that meets these criteria is Nakase Brothers, a 125-acre nursery in Lake Forest discharging into Serrano Creek and subsequently Reach 2 of San Diego Creek. Waste discharge requirements for this nursery are expected to be considered in August 2004. Other nurseries were investigated and found to be small retail operations under 5 acres, or, in some cases, not discharging waste to surface waters in the watershed (such as AKI, which uses hand-watering and recycled water).

Table 2-6: Nursery Allocations – Seasonal Loads

Nursery	2002 TN Actual Load (lbs/summer)	Allocation		
		2002 TN (lbs/summer)	2007 TN (lbs/summer)	2012 TN (lbs/winter)
El Modeno	36,409	40,992	38,613	14,227
Bordiers	267	12,993	12,261	4,518
Hines	2,382	7,859	7,320	2,697
Nakase	10,047 (<i>est</i>)	5,490	4,392	1,618
Total	49,105	67,334	62,586	23,060

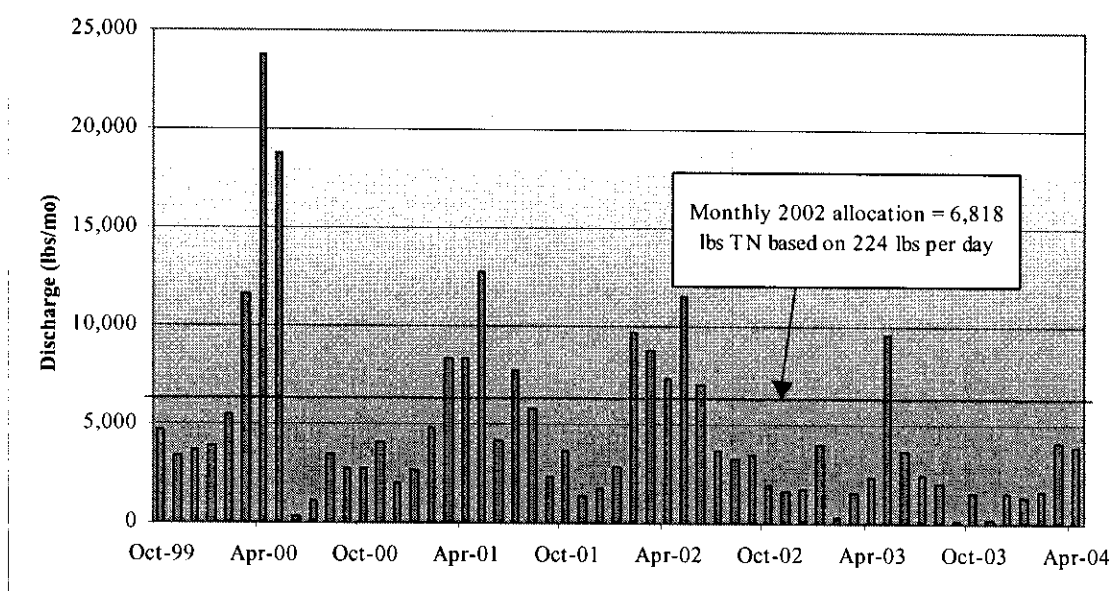
The nurseries operate year-round but have the highest plant volume in spring. Consequently, there is generally higher fertilizer use and nutrient runoff during the months of March to June, with substantially lower use and runoff in the remaining months.

Figure 2-6 shows the monthly total nitrogen load from Hines Nursery. The nursery typically exceeds the TMDL monthly limit during the spring months, although a declining trend is evident over the last three years. Summer season nitrogen discharges have decreased from over 50,000 lbs in 2000 to 36,409 lbs in 2002 and 20,199 lbs in 2003.

Hines' permit has not yet been revised to reflect the TMDL, and thus its current discharge limit is somewhat higher (264 lbs/month vs. 224 lbs/month). Hines has been upgrading its irrigation and drainage system and in January 2004, Hines representatives notified Regional Board staff that they had begun a water recycling program. As Hines Nursery accounted for about 30% of the summer nitrogen load into San Diego Creek in 2002, recycling rather than surface water

discharge would represent a substantial reduction in the amount of nitrogen transported into Newport Bay.

Figure 2-6: Hines Nursery Monthly Total Nitrogen Discharge: 1999-2004



2.4.2 Agriculture

In the late 1800s, agriculture in the San Diego Creek watershed consisted of sheep and cattle grazing on three large ranches, with only limited crop areas (Trimble 1999). Irrigated agriculture, including row crops and orchards, became important after 1900, and historical agricultural practices in the San Diego Creek watershed are believed to have contributed large amounts of nutrient runoff to the shallow groundwater aquifer and to Newport Bay.

According to the Orange County Farm Bureau (1998), furrow irrigation was the typical irrigation method prior to the 1970s, and fertilization was accomplished by injecting anhydrous ammonia (NH_3) directly into the irrigation water. On average, 25%-30% of the applied water would runoff the fields. With 45,000-50,000 acre-feet of water applied annually, the runoff volume probably accounted for roughly one-third the annual discharge volume of San Diego Creek. Assuming a runoff concentration of 20 mg/L, the annual nitrogen load would be approximately 610,000 lbs/yr, however some portion of this load would be lost through denitrification processes prior to entering Newport Bay. The baseline agricultural load estimate listed in the nutrient TMDL is 328,040 lbs/yr.

As shown in **Table 2-7**, the agricultural acreage in the watershed has been declining rapidly. The primary row crops grown in the watershed in 2001 were strawberries (431 ha), and tomatoes (166 ha). Miscellaneous crops, including beans and peppers, accounted for the remainder of the row crop acreage (French 2003). The 1,299 acres of orchards are largely avocado and are concentrated in the hillsides, while row crops are generally grown on the valley floor (Tustin Plain).

Table 2-7: Changes in Agricultural Land Use: 1982-2003

Crop Type	Agricultural Land Use (acres)		
	1982	2000	2003
Orchards	n/a	2,000	1,299
Row Crops	n/a	4,000	1,800
Total	21,000	6,000	3,099

Currently, agriculture in the San Diego Creek watershed is characterized by crops that have short growth cycles and high rates of return. Irrigation and land use costs are high. Partly as a result, agricultural practices emphasize efficient use fertilizers and conservation of water.

The nutrient TMDL included a task requiring development of an agricultural nutrient management plan (ANMP) for the watershed. Staff of the University of California, Cooperative Extension office in Orange County (UC-Coop) developed the ANMP for the San Diego Creek watershed in 1999, and began implementing the plan as part of a federal Clean Water Act project grant. The project components included monitoring, education/outreach, and BMP implementation (University of California Cooperative Extension [UCCE] 2003). The agricultural nutrient load for the summer 2002 season was estimated using data developed by this project.

On-site field evaluations performed in conjunction with the ANMP showed that growers had already adopted many of the BMPs recommended in the ANMP. These BMPs included the use of slow release fertilizer formulations, plastic mulch, soil and tissue sampling to determine nutrient levels, and soil moisture sensing devices to guide irrigation schedules (Haver 2003).

All commercial orchards in the watershed are irrigated using drip emitters or micro sprinklers. Row crops are irrigated using a combination of drip irrigation and overhead sprinkler applications. Furrow irrigation, a method that generates large volumes of runoff, is no longer used in the watershed (Haver 2003).

Strawberry planting begins in September, and the crops are harvested from late January to June. Irrigation is heaviest at planting, when overhead irrigation is employed to ensure establishment of the plants. Thus, most irrigation takes place largely during the winter season, and little runoff occurs during most of the summer.

Growers in the watershed apply nitrogen and phosphorus fertilizers to their fields at rates of 196-224 kg/ha (lbs/acre) for strawberries, and 100 -150 lbs/acre for avocado orchards. Under good agricultural practices, the crop takes up most of the applied fertilizer, and only a small percentage leaves the field in irrigation or stormwater runoff. A separate loss mechanism to the atmosphere is typically in the form of ammonia.

Total nitrogen loads over the past three-and-one-half years of monitoring at the row crop field sites average about 3.8 lbs/acre (on an annual basis), with 86 percent of the load occurring in the winter months. Assuming that the loading rates are applicable for the orchard areas as well, surface runoff loads are estimated at 1,673 lbs for the summer season, 10,103 lbs for the winter season, and 11,786 lbs for the entire year. A significant portion of the winter load (when the San Diego Creek flow rate exceeded 50 cfs) would not count towards the winter TMDL allocation.

Leaching: The load estimates presented above need to be adjusted upwards to account for leaching of nitrogen past the root zone. Growers typically intentionally over-water their fields in order to flush the root zone to prevent salinization. The amount of additional irrigation is referred to as the 'leaching fraction'. French (2003) estimated that the leaching fraction used by local

growers was between 15% and 25% of the required irrigation. This additional water percolates down through the soil, flushing nitrate into the shallow groundwater aquifer. The shallow groundwater eventually discharges to surface channels in the central or lower portion of the San Diego Creek watershed. Nitrate that reaches San Diego Creek via this pathway represents an additional load component. French (2003) estimated that about 7% of applied nitrogen fertilizer would leach past the root zone. This amounts to about 15,478 lbs TN discharged via groundwater on an annual basis, or about 31% of the 2012 total annual agricultural load allocation of 49,764 lbs (**Table 1-3**).

Adding the surface and groundwater pathways results in a total annual load of 27,264 lbs, or about 55% of the 2012 load allocation. Overall per-acre loading rates are then 8.8 lbs/acre. This rate is substantially below the loading rates of up to 99.7 lbs/acre cited during development of the TMDL in 1998 (Tetra Tech 1998). A major reason for the discrepancy is the absence of loading data from areas with climate and cropping patterns similar to the Newport Bay watershed; Tetra Tech had to rely on literature values based on data collected elsewhere.

Of the estimated 15,478 lbs of TN discharged through leaching to groundwater, an unknown portion occurs during the summer season. In the absence of seasonal percolation data, the summer nitrogen load due to leaching can be estimated by assuming that it is proportional to the amount of load discharged via surface runoff. Using this ratio, the summer load due to leaching is 2,200 lbs. Adding this estimate to the surface discharge load calculated using monitoring data (1,673 lbs) the total agricultural load for the 2002 summer season is thus 3,873 lbs.

2.4.3 Urban Runoff

The RMP states that compliance with the urban allocation will be determined from samples collected at the five monitoring stations listed in the box at right (SARWQCB - RMP 1999). Using the data provided by the RMP, the urban nutrient load is 25,391 lbs, about 22% over the 2002 summer season allocation.

Stations Used for Calculating Urban Load

1. Santa Ana-Delhi Channel at Irvine Ave.
2. Costa Mesa Channel at Highland Ave.
3. Lane Channel at Jamboree Rd.
4. El Modena-Irvine Channel at Michelle
5. Agua Chion Wash at Irvine Center Dr.

This calculation does not account for all urban sources in the watershed, but on the other hand, the five channels listed above do not drain exclusively urban subwatersheds. Although these channels are highly urbanized, they may contain discharges from other land uses, and particularly from rising groundwater and from groundwater cleanup or dewatering operations that discharge into these channels. These separate load sources need to be subtracted, and the entire urbanized area included in order to develop a more accurate estimate of the urban nitrogen load.

A separate estimate can be provided using the Residential Runoff Reduction (R3) Study results (Municipal Water District of Orange County 2004) and the urban acreage in the watershed. The per-acre nitrogen loading rates are on the order of 1.5 –2 lbs/acre, and are applicable to loading from the residential areas in the watershed. Using these per-acre loading rates for all urban areas in the watershed yields an overall urban load of about 130,000 lbs per year. The final annual TMDL allocation for urban areas is 72,070 lbs (**Table 1-3**). This suggests significant reductions in urban loads will be required in order to achieve the TMDL target.

The urban loads estimated using the per-acre load rates from the R3 Study are obviously much larger than those calculated using the five subwatersheds specified in the nutrient TMDL. The

difference arises because the five subwatersheds do not account for the entire urban land use in the watershed.

It is important to note however, that the overall summer loading rates from the San Diego Creek and Santa Ana Delhi subwatersheds are 0.585 lbs/acre and 1.62 lbs/acre, respectively. These rates are similar to the estimated loading rates derived from the R-3 Study and lower than previously used literature values (Tetra Tech 1998, 2000).

2.4.4 Silverado Constructors/CALTRANS

The Eastern Transportation Corridor (ETC) is an approximately 26-mile tollway built by Silverado Constructors (Silverado) to connect Interstate 5 to Route 91 in Orange County. A section of Highway 261, which forms the southern portion of the ETC, was constructed below the existing ground surface. Because of the shallow groundwater in the area, this section of the tollway requires permanent dewatering. Silverado constructed a passive subdrain system to intercept groundwater and maintain the groundwater table below the level of the tollway.

Silverado was issued a WDR/NPDES permit in January 1998, to discharge the intercepted groundwater to Peters Canyon Wash. The permit required Silverado to comply with the nutrient TMDL by reducing the nitrogen load by 50 percent and maintain concentrations below 13 mg/L.

Silverado constructed a denitrification facility to comply with the permit requirements. The denitrification facility employed a reactor to facilitate denitrification. Effluent concentrations averaged between 5 mg/L and 10 mg/L (well under the limit of 13 mg/L). The summer 2002 season discharge amounted to 6,516 lbs, only one-fourth of the permitted allocation in the TMDL.

Subsequently, Silverado ceased its responsibilities pertaining to the denitrification facility and the waste discharge requirements were transferred to the Transportation Corridor Agencies and CalTrans in late 2002. These revised requirements also included limitations that implemented the selenium TMDL for the Newport Bay watershed that was promulgated by the U.S. EPA in June 2002. Problems related to achieving the selenium limitations resulted in the diversion of the entire discharge from the denitrification facility to the Orange County Sanitation District sewer system, which transports the discharge out of the Newport Bay watershed and, ultimately, to the Pacific Ocean.

2.4.5 Groundwater Cleanup

Thirty-four facilities located in the Newport Bay watershed had enrolled in the general permit for groundwater cleanup operations prior to 2002. This permit was revised in January 2002, and special provisions were included for facilities located in the Newport Bay watershed. These provisions include requirements for nutrient monitoring and the formulation of plans for 50 percent reductions in nutrient loading. These plans are to be submitted for approval by the Regional Board's Executive Officer.

Partly as a result of the new requirements, some dischargers decided not to re-enroll under the new permit and elected instead to direct their discharges to the sewer. Low groundwater levels resulting from several drier than normal rainfall years, also meant that the wells at some facilities were dry and therefore no discharge occurred during the 2002 summer season.

Total loading from groundwater cleanup activities during the summer 2002 was approximately 1,574 lbs. However, because a number of facilities had not begun to collect sufficient nitrogen data, loading rates are estimates. The total combined discharge rate from all the cleanup operations was about 178,000 gpd (0.275 cfs). The overall flow-weighted average total nitrogen concentration was estimated at 8.7 mg/L.

The two MCAS cleanup facilities (Tustin and El Toro) accounted for about 60% of the estimated total load from groundwater cleanup operations. So far, 50% load reduction plans have not been implemented by any of the dischargers enrolled in the general permit.

2.4.6 Groundwater Dewatering

There were twelve facilities located in the Newport Bay watershed that were enrolled in the general groundwater permit for de minimis discharges, including dewatering operations, during the summer 2002 compliance period. This permit was last renewed in 1998 and included requirements for nitrogen monitoring for discharges in the Newport Bay watershed. New permits that will address groundwater dewatering and other groundwater-related discharges, as well as de minimis discharges within the Newport Bay watershed, are expected to be considered by the end of 2004. The new permits will include provisions to implement the nutrient TMDL and the toxics TMDLs promulgated in June 2002 for the watershed by the U.S. Environmental Protection Agency.

For the summer 2002 compliance period, the combined discharge from all facilities enrolled in the dewatering permit was about 700,000 gpd (1.1 cfs), and the flow-weighted total nitrogen concentration was 4.9 mg/L. The total load from dewatering operations for summer 2002 is estimated at 5,277 lbs. Dewatering facilities operated by the City of Irvine at Culver Ave. and at Jamboree Rd accounted for 87 percent of the load.

The City of Irvine dewatering facilities are located within a few miles of the Silverado/CalTrans denitrification facility. Shallow groundwater in this area contains high concentrations of nitrogen, largely as a result of previous agricultural practices in the watershed and the groundwater flow patterns in the watershed.

2.4.7 Rising Groundwater

Rising groundwater is also included in the 'undefined' source TMDL load allocation. The shallow groundwater contains high nitrate concentrations, primarily in the central part of the watershed. Numerous drainage channels intercept the shallow groundwater table and this 'rising groundwater' forms a significant portion of the flow in San Diego Creek.

The high nitrate concentrations in the shallow groundwater are largely a result of previous agricultural practices. These practices, including the use of flood irrigation and high fertilization rates for the previously predominant citrus crops, resulted in a significant flux of nitrate leaching through the root zone and down to the shallow groundwater.

This process of nitrate leaching has been reduced in recent decades as a result of two factors. First, land has shifted from agricultural land uses to urban uses, resulting in a large increase in the impermeable surface area and an overall decrease in the amount of fertilizer applied (although current urban/residential landscape management practices result in a continued input of nitrate to groundwater). Second, agricultural practices have changed; drip irrigation is now the main form of irrigation used for row crops, and slow release fertilizers reduce the net loss to leaching.

Nitrate concentrations in shallow groundwater are highest (over 25 mg/L) near the confluence of San Diego Creek and Peters Canyon Wash; elevated nitrate also occurs in the western-most region of Lane Channel. Nitrate concentrations decrease rapidly in a southwesterly direction towards Newport Bay. Southwest of the 405 Freeway, concentrations less than 1 mg/L TN are common based on data collected by permittees enrolled in the groundwater cleanup/dewatering permits.

Although it has been demonstrated that a large proportion of the flow in San Diego Creek is from groundwater (Hibbs 2000), the relative magnitude of the groundwater contribution has not been quantified conclusively. One method of quantifying the contribution is through analysis of conservative chemical markers for groundwater and surface water (Meixner et al., 2004). These chemical markers (EC, K, Cl, and SO₄) exhibit different ranges in groundwater and surface water. By comparing the median compositions, an estimate can be derived for the relative contribution of groundwater to the total flow in San Diego Creek. This estimate, ranging from 62% to 87% groundwater, is dependent on the reference surface water and groundwater types chosen, and subject to a number of simplifying assumptions.

These estimates, however, are supported by the discharge permit data: a total of 2.43 cfs was reported discharged to surface channels in the San Diego Creek watershed from groundwater cleanup and dewatering operations (including 1.07 cfs from Silverado) in summer 2002. The average flow rate in San Diego Creek during summer 2002 was 7.3 cfs, therefore the groundwater cleanup and dewatering facilities alone accounted for 33% of the total flow.

Subtracting this groundwater cleanup and dewatering discharge contribution from the total groundwater contribution estimated by Meixner et al, the flow rate derived from rising groundwater would be 29% to 54% of the total flow in San Diego Creek, or 2.1 cfs to 3.9 cfs, with a midpoint of 3.0 cfs (41% of total flow). Assuming an average groundwater concentration of 27 mg/L TN (using available well data), this would amount to a summer 2002 seasonal load of 80,156 lbs using the midpoint flow rate. As this estimate exceeds the measured load in San Diego Creek at the Campus Drive monitoring station, Meixner et al., (2004) suggest that significant nitrogen losses occur within Peters Canyon Wash and San Diego Creek (including the San Joaquin Marsh) prior to discharge to Upper Newport Bay.

The actual nitrogen load discharged to Upper Newport Bay calculated using data from the San Diego Creek Campus Dr. monitoring station was 45,507 lbs for the 2002 summer season (**Table 2-1**). Assuming 41% of the flow originates from rising groundwater, the TN load contribution from rising groundwater can be estimated as 18,658 lbs for the 2002 summer season.

2.4.8 Open Space Runoff

Open space accounts for a significant (though declining) portion of the total area in the watershed (**Table 1-1**). The largest remaining open space areas are located in the undeveloped foothills. These open space areas have been used historically as cattle and sheep ranches, but are unlikely to have been used for crop production.

Nutrient loading from open space areas occurs mostly during the winter season as a result of storm runoff. Winter season runoff from open space areas in Hicks Canyon and Rattlesnake Canyon was targeted for sampling by Meixner et al (2004). Flow was not observed in Rattlesnake Canyon, while the Hicks Canyon stormwater data (five samples collected over two days) ranged from 1.84 mg/L to 4.09 mg/L total nitrogen.

Although flows with these concentrations would result in significant stormwater loads, the nutrient TMDL excludes loads entering the Bay during periods when the flow in San Diego Creek exceeds 50 cfs. The mean daily discharge in San Diego Creek at Campus Drive was above 50 cfs during the days the samples were collected and for a day afterward. It is therefore not possible to estimate the winter season loading applicable to the TMDL that may originate from open space runoff.

For the summer season however, the open space runoff load contribution can be assumed to be negligible, except during unseasonable storms. The amount of flow produced by these storms can be quantified and multiplied by the measured concentrations above to generate the load. For the summer season 2002 there were no such unseasonable storms.

2.4.9 Atmospheric Deposition

Published estimates for the relative contribution of atmospheric deposition to nutrient loading to estuaries range from about 10-45%, with the variability largely dependent on the size of the estuary and its watershed (NOAA 1996).

The contribution from atmospheric deposition was unknown at the time the Newport Bay nutrient TMDL was established, thus it was included in the undefined source allocation. As part of a contract to address un-quantified sources, Meixner et al (2004) monitored nitrogen deposition from the atmosphere using an *Aerochem 301* bucket collector installed at the University of California's San Joaquin Marsh Research Reserve. Total dry deposition was monitored on a bi-weekly basis for a period of 18 months beginning in June 2002 and continuing through summer 2003. Wet deposition was also monitored during rainfall events (Meixner et al 2004).

The dry deposition rate for inorganic nitrogen varied from a low of 1.4 lbs/acre up to a high of 10.7 lbs/acre on an annual basis. The mean annual rate of dry deposition was 3.9 lbs/acre. The annual load to Upper Newport Bay at the mean deposition rate is 2,952 lbs.

The deposition rate for the rain events sampled was about 0.67 lbs/acre, only about 17 % of the mean dry deposition rate. Annual loading from wet deposition would amount to 503 lbs/yr. The low wet-deposition results from the study by Meixner et al confirm previous results from rainwater samples collected by the OCPFRD.

The variability in dry deposition rates seems to be driven by meteorological changes. Higher rates of atmospheric deposition occur in the fall in conjunction with Santa Ana wind events that bring airborne particles from inland areas, while the prevailing wind pattern in late spring and summer produces an onshore flow, and a foggy marine layer over the bay results in reduced atmospheric deposition rates.

Because not enough data were collected to clearly distinguish between winter vs. summer loading rates, an appropriate estimate for the summer season atmospheric deposition load would be ½ the annual load, or 1,476 lbs. This amounts to less than 5% of the 2002 summer season load. The lower rate of atmospheric deposition relative to literature available from other estuaries is likely due to the prevailing onshore wind patterns that transport atmospheric nitrogen eastward and out of the watershed.

The origin of nitrogen deposited in the watershed is likely to be from both local sources and from sources outside the watershed. The main source of nitrogen oxides in air is from high-temperature

combustion (industry, power plants, automobiles, etc.). Other sources could include emissions from fertilized lawns/gardens and agricultural fields (NOAA 1996).

The channel monitoring data implicitly account for nitrogen runoff originating from indirect deposition.

2.4.10 In-Bay Nitrogen

SCCWRP experiments have shown that macroalgae in Newport Bay can utilize nutrients from sediments, particularly when water column nutrient concentrations are low (SCCWRP 2002). A variety of factors likely influence the magnitude of the nutrient flux to macroalgae from sediment. Winter stormwater flows deposit fresh sediment in the bay on an annual basis, however, the sediments are subject to twice-daily tidal flushing that gradually leaches nitrogen out to the ocean. Decomposition of organic matter produces ammonia nitrogen that is readily available for uptake by algae, however, nitrogen is also lost from sediment mudflats to the atmosphere.

The available monitoring data from San Diego Creek suggest that in-bay nitrogen may be a significant source. Particulate nitrogen (nitrogen associated with sediment and organic matter) entering the Bay during storm events is likely to settle and remain associated with sediment in the Bay. This winter load is currently not regulated, and even in 2012, the target date for achievement of the TMDL winter load allocation, most of this load would be transported into the Bay during storm events when the flow rate in San Diego Creek was over 50 cfs, and thus would be exempt from the TMDL.

Biological and chemical processes could, over time, result in transformation of this nitrogen into ammonia, a form that is available for uptake by macroalgae. Although the particulate organic nitrogen is currently not measured, the total organic nitrogen load in 2000/01 was 73,000 lbs. If even one-fifth of this load consisted of particulate organic nitrogen that remained in the Bay and was rendered bio-available during the summer season, then the annual in-bay sediment loading for the summer season would exceed 10,000 lbs. Added to this annual load from a moderate or low-rainfall year, there would be a legacy component from previous years when the storm loading and sediment/particulate transport into the Bay was extremely high. Thus, the in-bay sediment loading could easily exceed 15,000 lbs for the summer season (i.e., greater than 10 percent of the entire seasonal TMDL target).

A SCCWRP study, scheduled for completion in September 2005, is currently under way to estimate the magnitude of in-bay nitrogen sources. The objectives of the study are to *“(1) Determine rates and environmental factors controlling sediment-water column nutrient exchange, (2) Examine relationships between sediment nutrient flux and macroalgal biomass and tissue nutrient status, (3) Compare magnitude of nutrient loading from sediments to other nutrient inputs to the Bay, and (4) provide data necessary to refine the water quality model for the Bay.”*

The study will use isotopic analysis to determine the annual deposition rate of new sediment in Upper Newport Bay, estimate seasonal flux rates using data collected in the field and in the lab, and quantify the magnitude of in-bay nitrogen loading to the waters of the Upper Bay.

2.4.11 Other Sources

A discharge permit was issued in 2002 for surface water discharges from the City of Tustin's 17th Street Desalter Facility. Discharge from this facility only occurs during startup and shutdown operations, and during any stoppages of the treatment system. The permit specified a nitrogen discharge allocation of 300 pounds per year; 146 lbs for the summer season and 157 lbs for the winter season, and a 50 percent reduction to be achieved by 2007. Actual discharge for the Summer 2002 season was 148 lbs, slightly above the permit limit. The desalter removes total dissolved solids and nitrate from groundwater, some part of which would otherwise rise naturally into surface waters. The magnitude of the reduction entering surface waters as the result of the desalter operation has not been quantified.

The IRWD Wetlands Water Supply Project, which received a winter season only allocation of 62 lbs/day total nitrogen, was never implemented and the permit expired in 1999.

2.5 San Joaquin Marsh – IRWD and UCI Wetlands

A major factor affecting nitrogen loading to Newport Bay is the diversion of a portion of the flow in San Diego Creek (roughly 50%) into the adjacent IRWD and UCI wetlands, which are part of the San Joaquin Marsh. The marsh is a remnant of a previous era when the Santa Ana River meandered across the coastal plain to reach Newport Bay. After the Santa Ana River shifted course, the marsh received only a limited amount of water from the surrounding areas. (The Santa Ana River is currently routed directly to the sea, and does not flow through the Newport Bay Watershed). By 1915, expansion of irrigated agriculture resulted in a drainage channel network that terminated in 600 acres of peat and swampland near the head of Newport Bay. Urbanization and further expansion of agriculture eventually led to drainage from the entire watershed being routed through San Diego Creek to the Bay. The Creek was extended to the bay and isolated from the marsh in the 1960s (Trimble 1998, et al).

The San Joaquin Marsh currently consists of the 202-acre reserve managed by UCI, and the roughly 67 acres of ponds and wetland vegetation in the adjacent IRWD wetlands across Campus Drive to the east. UCI has recently submitted an Initial Study for Phase II of the Marsh Restoration Plan (UCI, 2003). The plan would increase water exchange between the marsh and San Diego Creek, and this would likely result in additional denitrification. However, since the load monitoring station for the TMDL is at Campus Drive, the nitrogen reduction associated with the UCI marsh will not be included in the TMDL load calculations, unless and until the TMDL is revised.

The IRWD wetlands however, are currently a major factor in reducing nutrient loads to Newport Bay. Water is diverted into the wetlands at an average rate of 5 cfs and circulated through a series of ponds before being returned to the creek (IRWD 2004). The residence time in the wetlands is roughly two weeks. Water consumption/loss is minimal, but nitrogen concentrations are reduced from 25% to 75% depending on various factors, primarily temperature and input concentration.

For the calendar year 2002, IRWD calculated that the wetlands removed about 66,000 lbs of total nitrogen (IRWD 2003). In the absence of more detailed data, the summer 2002 load removal is estimated as 33,000 lbs (½ the annual total).

3.0 MACROALGAL TRENDS IN NEWPORT BAY

The macroalgal blooms in Newport Bay are composed of two genera: *Enteromorpha* and *Ulva*, and exhibit distinct seasonal patterns of biomass accumulation in upper Newport Bay. *Enteromorpha* and *Ulva* are generally sparse in the winter and early spring, when growth is likely to be limited by environmental factors such as light and temperature. However, they are prolific throughout the summer and fall, when light and temperature conditions are optimal for growth (SCCWRP 2000).

A distinguishing feature of *Enteromorpha* and *Ulva* is their ability to grow rapidly under conditions of enriched nutrient availability. Uptake rates measured in the lab exceed those observed for other genera of algae by two orders of magnitude (SCCWRP 2003). Rapid growth allows these algae to out-compete other marine organisms and dominate the intertidal habitat where they are most commonly found. Under normal conditions of nutrient supply however, *Enteromorpha* and *Ulva* are less successful in competing with other marine organisms and are also subject to grazing by herbivores.

A monthly macroalgal survey has been taking place in Upper Newport Bay since 1996. The survey, currently being conducted by the County of Orange under the supervision of Dr. Alex Horne, was made part of the RMP beginning in 2001. The eight survey stations currently being sampled are situated in mudflats distributed from the head of the Bay to the Dunes area. Sampling is conducted using a randomly located 0.1 m² quadrant. Algae within the quadrant are collected by hand, and cleaned in the field with local seawater to remove mud and debris. The algae are then spun in a field centrifuge to remove water and the damp algae are weighed using a field balance (Horne 2003). Three replicates are collected from each station.

The inherent patchiness of algal growth patterns results in a great deal of variability in algal biomass measurements, even among the three replicate samples collected at each station. Consequently, it is not possible to make statistical biomass comparisons between seasons and years without greatly increasing the sample size and the number of replicates.

In general terms however, the data indicate that the extent and duration of macroalgal blooms has decreased since initiation of the TMDL. The lower bay is now largely free of macroalgae, while blooms in the upper bay are less extensive than in prior years.

Nitrogen and phosphorus data collected from each algal sample also indicate that algae in the stations furthest from San Diego Creek are deficient in nitrogen relative to phosphorus, (ratio below 10:1) indicating that at these sites, the available nitrogen supply is below the optimum level for rapid growth (Horne 2003). Algal tissue from sites closest to San Diego Creek, however, still indicated that sufficient nitrogen was available for growth. This suggests that further reductions in nitrogen loading are required to continue reducing the macroalgal biomass in Upper Newport Bay.

Visual evidence indicates that fall blooms, extending through November, continue to generate virtually 100% coverage of the mudflats in most of the upper bay. The highest observed biomass occurred during 1998 and appears to have been stimulated by sediment-associated nutrients that were released into the water column during dredging of Upper Newport Bay in 1998.

4.0 TASK STATUS AND SCHEDULE

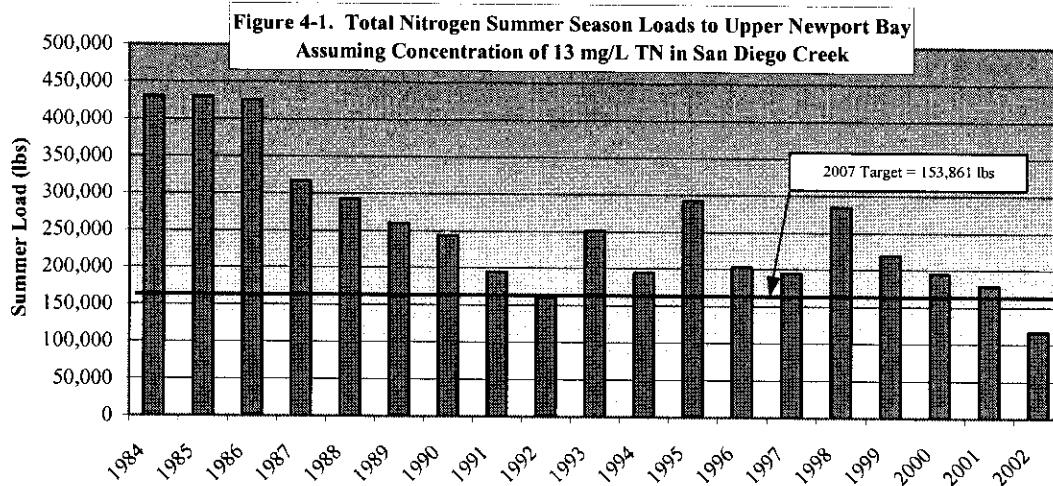
Table 4-1 provides an update of the TMDL tasks and the current status of each task. Each task is discussed in further detail below.

Table 4-1: TMDL Task Status

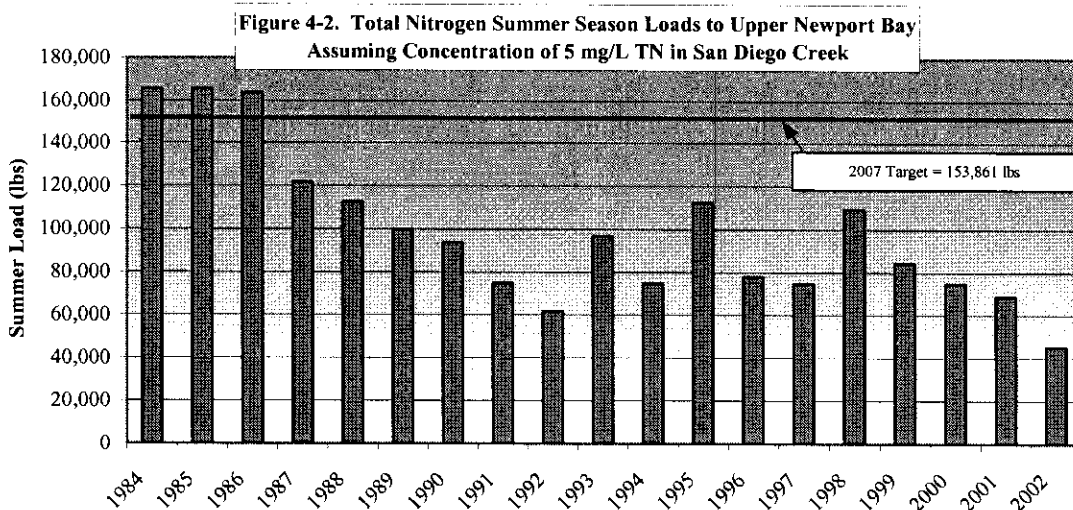
Task	Description	Status
Phase I:		
1	Review TIN objectives in San Diego Creek and revise if necessary	Strategy designed to link quantitative impacts to WQOs using a water quality model. Several studies have been completed, but at least 3-years work remains.
2	Establish new WDR permits	Nakase permit scheduled for 2004
3a	Revise existing WDR permits	Bordiers revised 2003; El Modeno, Hines – 2004/2005
3b	Revise existing NPDES permits.	O. C. MS4 permit and groundwater cleanup general permit revised 2002. Other permits revised (see below)
4	Agricultural nutrient management program	Plan approved by Regional Board in 1999. UC Coop completed contract to implement the plan (2000-2003)
5	Urban Stormwater: nutrient load management analysis.	Compliance evaluation submitted in 2000. O.C. contract for urban BMPs to be completed in 2005
6	Sediment TMDL for control of phosphorus	Sediment TMDL under implementation
Phase II:		
1	Self-monitoring or participation in <u>Regional Monitoring Program</u> (RMP); investigate unknown sources.	Permit-related monitoring revised as above. The Regional Board approved the RMP in 1999 - reports are submitted annually in November by Orange County
2	Actions and Schedule to Achieve Water Quality Objectives	Review TMDL, WDRs and compliance schedule at least once every 3 years

Task 1 – Review of Water Quality Objectives in San Diego Creek

The water quality objectives in San Diego Creek were established in the 1970s. The TMDL requires review of these objectives and the establishment of new objectives if appropriate. The 13 mg/L total inorganic nitrogen (TIN) objective for Reach 1 is clearly not protective; nutrient loads calculated using summer season flow data and an assumed TN concentration of 13 mg/L greatly exceed the final summer season TMDL goal in all but two years from 1984-2002 (**Figure 4-1**).



The theoretical loading shown in **Figure 4-1** has been adjusted upward by 21% to account for the additional sources to Newport Bay (tributary channels other than San Diego Creek, and atmospheric deposition), but it does not account for in bay loading (sediment). Repeating the above exercise with an assumed TN objective of 5 mg/L (**Figure 4-2**) results in achievement of the TMDL in all except the first three years (1984-1986). This indicates that the revised WQO for Reach 1 of San Diego Creek should be less than 5 mg/L. In light of evidence (continued algae blooms in Upper Newport Bay) that the TMDL load targets are not themselves sufficiently protective and need to be reduced, the revised WQO will likely need to be substantially less than 5 mg/l.



The derivation of appropriate nitrogen WQOs in San Diego Creek to protect the beneficial uses of Newport Bay is hampered by the lack of a direct, quantifiable link between inflow nitrogen concentrations or loads and macroalgal biomass.

Progress has been made in understanding and quantifying the mechanisms causing eutrophication in Newport Bay, however much work remains to be done. A literature review performed by SCCWRP, *Comparison of Nutrient Inputs, Water Column Concentrations, and Macroalgal Biomass in Upper Newport Bay, California* assessed whether the existing water quality objectives

in San Diego Creek were appropriate in comparison with other estuaries (SCCWRP 2001). The review found that water column concentrations were weakly correlated with macroalgal biomass in all estuaries studied, and particularly in Newport Bay. This was due in part to the potential existence of significant secondary mechanisms (such as nutrient storage in sediment and tissue) that obscure the concentration-biomass relationship.

These secondary mechanisms were confirmed by experiments conducted using sediment and water from Upper Newport Bay. The experiments demonstrated that *Enteromorpha* utilized sediment nutrient sources when water column concentrations were low. Also, algae were able to store enough nutrients from the large one-time pulses of nutrient inputs to sustain positive increases in biomass in low nutrient environments for up to 28 days (SCCWRP 2002). Quantification of the role played by sediments is currently being studied and the results should help complete a nitrogen conceptual model and mass balance in Newport Bay.

Efforts to quantify the link between nitrogen concentrations in San Diego Creek and water quality impairments in Newport Bay are currently focused on dissolved oxygen. A SCCWRP report: *Dissolved Oxygen as a Potential Indicator of Water Quality in Newport Bay: A Review of Scientific Research, Historical Data, and Criteria Development*, (SCCWRP 2003) outlines the steps needed to establish appropriate dissolved oxygen thresholds that could be incorporated in to the nutrient TMDL as endpoints.

A water quality model has been developed for Newport Bay and refined to account for significant algal nutrient supply mechanisms such as internal storage (RMA 2003). The model calculates algal biomass and dissolved oxygen concentrations throughout the bay. This information can be used to set appropriate nitrogen WQOs in San Diego Creek that will not produce algal blooms that are extensive enough to cause impairments by lowering dissolved oxygen concentrations to unacceptably low levels. Current model results are subject to large degrees of uncertainty. Successful application of the model in a predictive mode is dependent upon completion of on-going and planned studies in Newport Bay that will provide data on input parameters relating to sediment nutrient supply and dissolved oxygen..

The schedule to complete the scientific studies, calibrate the water quality model, and perform simulations to determine appropriate WQOs for San Diego Creek is likely to extend for more than three years, i.e. beyond 2007.

Separately, a statewide working group is formulating a plan to develop nutrient criteria that will be acceptable to the U.S. EPA national nutrient criteria development program. Current U.S. EPA recommended criteria are based on an eco-regional approach and are less than 1 mg/L, substantially below the objectives currently established in the watershed.

Tasks 2 & 3 – Establish New Permits; Revise Existing Permits

The TMDL directed that Waste Discharge Requirements be issued to un-regulated nursery operations of 5 acres or more that discharge nutrients in excess of 1 mg/L. As described previously, the only nursery in the watershed that meets these criteria is the Nakase Brothers Nursery. Waste discharge requirements for this nursery are expected to be considered in late summer 2004. Revised waste discharge requirements for the other large nurseries in the watershed (Bordiers, Hines and El Modeno) have been adopted or will be considered by the end of 2004.

The areawide urban stormwater permit for Orange County and the general groundwater cleanup permit have been revised to incorporate nutrient TMDL requirements. The waste discharge requirements for the Silverado/CalTrans denitrification facility were also revised to reflect the change in ownership/operation to CalTrans/Transportation Corridor Agencies and to incorporate selenium requirements necessary to implement the selenium TMDL promulgated by the U.S. Environmental Protection Agency in June 2002 (with other toxic substance TMDLs). The NPDES permit for the Tustin Desalter was revised to require a 50% reduction in total nitrogen discharge by 2007.

The Regional Board is expected to consider a new permit that will address discharges in the Newport Bay watershed that, to date, have been regulated under the general de minimis discharge permit. The new permit, which is scheduled for consideration in August 2004, will regulate short-term (less than one year) groundwater-related discharges as well as de minimis discharges within the watershed. The permit will assure implementation of relevant requirements of the nutrient and toxic substance TMDLs. In addition, individual permits for long-term groundwater related discharges, such as those associated with dewatering activities by the City of Irvine, are being developed and are expected to be considered in late summer/early fall 2004. An individual permit for groundwater cleanup operations at the MCAS Tustin is also being developed to address TMDL requirements.

Task 4 – Agricultural Nutrient Management Program

The Agricultural Nutrient Management Program was approved in 1999. Implementation of the program was coordinated by UCR and the UC Cooperative Extension pursuant to a Federal grant awarded under Section 319h of the Clean Water Act. This grant agreement concluded in December 2003. UC Coop extension staff conducted education and outreach activities, farm inspections, and tested BMPs for effectiveness in reducing nutrient loads from the agricultural areas of the watershed. Further details can be found in the final report (UC Coop, 2003).

Task 5 – Urban Stormwater Nutrient Load Evaluation

An evaluation report was submitted by Orange County in 2000. The report included recommendations for source characterization and BMP evaluation. These recommendations are being implemented through a Prop 13 contract awarded to Orange County and scheduled for completion in 2005.

Task 6 – Sediment TMDL for Control of Phosphorus

The sediment TMDL is under implementation. Annual reports are submitted in November of each year. Due in large part to the low rainfall levels in the past few years, sediment loads have remained well below levels established in the sediment TMDL. The phosphorus load is an order-of-magnitude (90%) below the allocation established in the nutrient TMDL.

Phase II Task 1 – Monitoring and Investigation of Unknown Sources

The Regional Monitoring Program was approved in 1999. Annual reports are submitted in November of each year, with the first report submitted in 2001.

Phase II Task 2 – TMDL Review

A summary review report was prepared and presented to the Regional Board in November 2000 for the first triennial review period. (The current report constitutes the second triennial review).

5.0 CONCLUSIONS/RECOMMENDATIONS

Conclusions

1. The overall TMDL load and wasteload allocation targets for summer season 2002 and 2007 have been achieved.
2. The 13 mg/L total inorganic nitrogen WQO in Reach 1 of San Diego Creek has been achieved, however the 5 mg/L total inorganic nitrogen WQO in Reach 2 has not been achieved and the data show no indication of progress towards achieving the objective.
3. Achievement of these targets and objectives was largely due to three factors: (a) low rainfall, (b) denitrification in the IRWD wetlands in San Joaquin Marsh, and (c) nitrogen runoff control efforts in the watershed particularly at the nurseries and the Silverado/Caltrans dewatering facility.
4. Algal blooms are still occurring in Newport Bay, although overall algal biomass appears to show a declining trend.
5. The continuing occurrence of algal blooms demonstrates that the WQOs in San Diego Creek are not protective enough and should be lowered. The 13 mg/L WQO is inconsistent with the TMDL and should be lowered to less than 5 mg/L. The summer season average TN concentration for 2002 was 5.6 mg/L. This suggests that a lower objective would be feasible given that additional nitrogen runoff control and treatment measures are in the process of being implemented in the watershed.
6. The water quality objective of 5 mg/L in Reach 2 of San Diego Creek will likely not be achieved without additional treatment facilities targeting shallow groundwater. Issuance of new permits for the City of Irvine dewatering facilities and for the Nakase Brothers Nursery should result in lower concentrations. However, the TMDL target (14 lbs/day) does not appear feasible, as it would require an objective of less than 1 mg/L (using the average flow rate of the creek).
7. Even if the water quality objectives in San Diego Creek, and TMDL loads to UNB are drastically reduced, nutrient sources in the sediments/mudflats may continue supporting algal blooms for an indefinite period into the future.
8. Linking water quality objectives to the algal blooms is a difficult scientific problem. Progress has been made but further work is required and underway. Application of the water quality model to determine appropriate WQOs in San Diego Creek with a requisite level of certainty will probably not be possible until 2007 or later.

Recommendations

1. The TMDL can be updated/revised with new information concurrent with establishment of the new WQOs for San Diego Creek. Potential TMDL revisions include:

- Updating the “undefined” load category to incorporate new source characterization data developed in the five years since the TMDL was adopted
 - Recalculating the urban and agriculture load allocations to account for land use changes
 - Removing the IRWD WWSP load allocation, and adding new dischargers such as the Tustin Desalter, and adding the large City of Irvine dewatering operations as separate load allocations
 - Increasing the overall TMDL goal (e.g., to a 70% reduction) to address continuing algal blooms. This would require a uniform reduction in allocations.
 - Revising the winter season 50 cfs storm exemption to account for new modeling results that demonstrate the potential for sediment-associated nitrogen to accumulate in the Bay during the winter season
2. The most efficient manner to revise the TMDL would be to address all the changes with a single Basin Plan amendment. This would require postponing revisions until 2007 at the earliest in order to allow completion of the water quality objective revision task.

6.0 REFERENCES

- Blodgett, Patricia 1989. Newport Clean Water Strategy – A Report and Recommendations for Future Action. Report to Santa Ana Regional Water Quality Control Board
- French, Christine 2003. Modeling Nitrogen Transport in the Newport Bay/San Diego Creek Watershed. A Thesis Submitted in Partial Satisfaction of the Requirements for the Degree of Master of Science in Environmental Sciences
- Haver, Darren, 2003. Personal Communication
- Hibbs, Barry 2000. Nitrate in the San Diego Creek Watershed. Prepared for Defend the Bay and the California Urban Environmental Research and Education Center
- Horne, Alex 2003. Eutrophication in the Newport Bay Estuary in 2002: Trends in the Abundance of Nuisance Macroalgae (Seaweeds) in 1996-2002. Report to: Orange County Public Facilities and Resources Department
- Irvine Ranch Water District (IRWD), 2004. San Joaquin Marsh Nutrient Removal Summary, Presentation by Jim Hyde at TMDL review workshop, Irvine
- IRWD, 2004. Natural Treatment System, Revised Draft Environmental Impact Report
- Meixner et al., 2004. Sources of Selenium, Arsenic, and Nutrients in the Newport Bay Watershed, (Contract Report to the SARWQCB).
- Municipal Water District of Orange County 2004. The Residential Runoff Reduction Study.
- National Oceanic and Atmospheric Administration (NOAA) 1996. Atmospheric Nutrient Input to Coastal Areas; Reducing the Uncertainties. NOAA Coastal Ocean Program, Decision Analysis Series No. 9
- Orange County Environmental Management Agency (OCEMA) 1989. Water Quality Trends in Newport Bay
- Orange County Farm Bureau 1998. Comments on the Basin Plan Amendment, Nutrient Total Maximum Daily Load, Newport Bay/San Diego Creek Watershed
- Orange County Public Facilities and Resources Department (OCPFRD) 2001. Report of the Regional Monitoring Program for the Newport/San Diego Creek Watershed Nutrient TMDL
- OCPFRD 2002a. Report of the Regional Monitoring Program for the Newport/San Diego Creek Watershed Nutrient TMDL
- OCPFRD 2002b. San Diego Creek Sediment Monitoring Program; 2001-2002 Annual Report
- Resource Management Associates (RMA) Inc. 2000. Newport Bay Water Quality Model Documentation
- RMA Inc. 2003. Newport Bay Water Quality Model Update

Santa Ana Regional Water Quality Control Board (SARWQCB), 1997. Staff Report for the Regional Board meeting of September 12, 1997 (nutrient TMDL workshop)

SARWQCB 2000, Status of Implementation of the TMDL for Nutrients in the Newport Bay/San Diego Creek Watershed. Staff report for the Regional Board meeting of November 17, 2000

Southern California Coastal Water Research Project (SCCWRP) 2000. Comparison of Nutrient Inputs, Water Column Concentrations, and Macroalgal Biomass in Upper Newport Bay, Technical Report 332

SCCWRP 2002. Macroalgal Nutrient Dynamics in Upper Newport Bay, Technical Report 365

SCCWRP 2003. Dissolved Oxygen Concentration as a Potential Indicator of Water Quality in Newport Bay: A Review of Scientific Research, Historical Data, and Criteria Development, Technical Report 411

Tetra Tech, Inc. 2000. Newport Bay Watershed Urban Nutrient TMDL Compliance Evaluation, Prepared for County of Orange – Public Facilities and Resources Department

Tetra Tech, Inc. 1998. Draft Nitrogen Loading Assessment for San Diego Creek, California. Prepared for EPA Region 9 and Santa Ana Regional Water Quality Control Board

Trimble, S.W. 1998. Historical Hydrographic and Hydrologic Changes in the Newport Bay-San Diego Creek Watershed. Report submitted to the County of Orange – Public Facilities and Resources Department

University of California Cooperative Extension, Orange County (UCCE) 2003. Agricultural BMP Implementation Within the Newport Bay/San Diego Creek Watershed. Report to the Santa Ana Regional Water Quality Control Board.

University of California, Irvine, 2003. Draft Negative Declaration, San Joaquin Freshwater Marsh Reserve, Phase II Restoration Plan